Research Paper

Comparing the Knee Valgus Angle and Pattern of Dominant and Non-dominant Feet in Basketball Players With Dynamic Knee Valgus After Fatigue

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ABSTRACT

Purpose: Since the foot is vital for maintaining stability and posture, knowing the difference between dominant and non-dominant knees can help reduce the risk of knee injury. Basketball players with dynamic knee valgus (DKV) following fatigue application were the subjects of the current study, which compared the angle and pattern of knee valgus in dominant and non-dominant feet.

Methods: In this cross-sectional study, our selection process involved choosing 27 basketball players with a knee dynamic valgus pattern (mean age=20.77±3.06 years, mean height=188±9 centimeters, and mean weight=79.68±18.35 kilograms) in a non-random, targeted manner. To assess the knee valgus angle in the frontal plane, we performed imaging using a digital camera positioned at 366 centimeters and a height of 105 centimeters relative to the subject. Furthermore, the subjects performed three countermovement jumps. Data were analyzed using "KINOVEA" software, version 0.9.5. In this study, players engaged in a 40-minute basketball game, conducted under regulations and including all scheduled rest periods.

Results: No significant difference was observed between the pre-test and post-test in the dominant foot initial contact valgus variable (P=0.900), non-dominant foot initial contact valgus variable (P=0.134), dominant foot maximum flexion valgus variable (P=0.237), and non-dominant foot maximum flexion valgus variable (P=0.188), according to the results of the paired t-test for within-group comparison of the study's mean variables. Furthermore, no statistically significant difference was observed in the first contact valgus between the dominant and non-dominant foot prior to the test (P=0.485) or between the two groups after the test (P=0.066). However, a significant difference was found in the maximum flexion valgus between the dominant and non-dominant foot before the test (P=0.012) and after the test (P=0.018), indicating that the dominant foot had a greater valgus angle than the non-dominant foot in both instances.

Conclusion: The current study's results indicate that functional exhaustion, as employed in this investigation, does not raise the knee valgus angle; however, among basketball players, the dominant foot's valgus angle was larger than the non-dominant foot. Therefore, the basketball players' dominant foot is probably more vulnerable to non-contact anterior cruciate ligament (ACL) injuries.

Keywords:
Dominant and non-dominant foot, Basketball, Dynamic knee valgus (DKV), Fatigue

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Highlights

● In basketball players with dynamic knee valgus (DKV) abnormalities, playing the game does not increase the valgus angle of the dominant and non-dominant legs.

● No difference is observed in the initial contact valgus angles between the dominant and non-dominant legs in basketball players with DKV deficit; nevertheless, they show increased maximal and peak valgus angles compared to the non-dominant leg.

● The difference in valgus angle between the dominant and non-dominant legs may stem from basketball's unique style and game, which involves more single-leg jumps and landings.

Plain Language Summary

They found that men's natural DKV angles ranged from 3-8 degrees during two-legged landings to 1-9 degrees for one-legged landings. The natural valgus angle during a single-leg squat with a knee flexion angle of 60 degrees is 7.08 degrees in the right leg and 8.68 degrees in the left leg in volleyball and basketball players with an average age of 14.21 years. The valgus angle in the left leg of basketball players is noticeably less than volleyball players, and this discrepancy can be due to variations in the particular strategies used in each sport. Although the non-dominant leg is less strong than the dominant leg, the dominant leg sustains more anterior cruciate ligament (ACL) injuries. Additionally, statistics show that injuries happen more often later in the game, pointing to a connection between weariness and injury. It is crucial to evaluate how exhaustion affects an athlete's performance during a sporting event. Consequently, using a digital camera to evaluate the dynamic valgus angle of their dominant and non-dominant legs, 27 basketball players with DKV abnormalities participated in this study. The participants then participated in individual basketball games, keeping to scheduled game periods for each session. The dynamic valgus angles of participants' dominant and non-dominant legs were once more captured by the camera during this period, and subsequently processed using KINOVA. A distinction was observed in the valgus angles between the two legs, with the dominant leg exhibiting a larger valgus angle than the non-dominant leg. The results indicated that exhaustion did not lead to an increase in the valgus angle for either the dominant or non-dominant leg. This suggests that the dominant limb is at a greater risk for non-contact ACL injuries.

Introduction

Stiffness in the neuromuscular system can lead to dynamic instability of the knee. Dynamic knee instability, sometimes referred to as knee valgus, is the result of a multitude of lower limb motions and rotations, including hip adduction, internal rotation, knee abduction, tibial external rotation, and anterior displacement of the tibia [1]. Anterior cruciate ligament (ACL) damage is more likely to occur when aberrant lower limb neuromuscular activity aggravates the degree of knee valgus. [2]. On the other hand, joint stress and the chance of ACL injury during sports activities are increased by neuromuscular dysfunctions, which are the main cause of non-contact ACL injuries in athletes [2]. In an investigation conducted in 2010 to determine the standard knee valgus angle in physically active individuals, it was shown that men naturally exhibit a knee valgus angle of 3-8 degrees while landing on two legs and 1-9 degrees when landing on one leg. In addition, the results of an independent 2011 study that aimed to determine the average dynamic knee valgus (DKV) in 14.21-year-old male and female basketball and volleyball players showed that the natural valgus angle in the right and left legs during a single-leg squat with a knee flexion angle of 60 degrees is 7.08 degrees and 8.68 degrees, respectively [3]. An injury or disturbance of knee stability can be caused by some causes, one of which is weariness, centrally and environmentally [4]. When metabolic exhaustion sets in during exercise and impairs dynamic knee joint stability, there may be a higher chance of knee injury [5]. Increased pressures and torques on the knee as well as disruptions in joint stability under fatigue circumstances are primarily caused by diminished muscle force, poor coordination, and delayed neuromuscular activation [6]. Furthermore, evidence points to a correlation between weariness and injury, with a larger proportion of injuries occurring around the end of games [7]. Thus, it is essential to assess how weariness affects an athlete's performance throughout a sporting event. While the effects of weariness have been extensively documented in the literature on sports science, very few studies have looked at how an actual game affects an athlete's performance. Neuromuscular exhaustion is one variable that may be altered to potentially affect the risk of lower limb injury. [8-10]. Two types of exhaustion come from exercise that causes a decrease in muscular power, environmental fatigue and central fatigue [11]. Physiological mechanisms suggest that external weariness primarily arises in metabolic systems following neuromuscular junctions, whereas central exhaustion develops in the neurological system before neuromuscular junctions [11]. These pathways modify neuromuscular regulation and reduce muscle's capacity to produce appropriate function [12]. Numerous fatigue procedures have been utilized in previous research. Protocols for mitigating environmental fatigue focus on certain muscles and are brief [8, 13]. Conversely, long-term central fatigue protocols target the cardiovascular system as well as motor control. They involve agility workouts that mimic more realistic sports postures, such as jumping and running on a treadmill [8, 10, 11] can be applied to evaluate basketball players' weariness. These guidelines resemble basketball rules in part [14, 15]. Throughout a basketball game, they comprise alternating workouts that incorporate running, jumping, direction changes, running, and recuperation [15]. A study using a basketball practice simulation protocol observed decreased quadriceps muscle strength, which significantly affected jump performance and sprint speed [15]. Furthermore, athletes' landing biomechanics were adversely affected by the use of an intermittent workout routine that replicates the demands of a ninety-minute football game [16, 17]. The literature on sports science suggests trustworthy methods available for accurately modeling particular sports tasks. Nonetheless, most research employs techniques within synthetic laboratory settings, which differ significantly from actual gaming environments. Therefore, conducting a field study in a basketball training session would be interesting. Since landing jumps are frequent in basketball and knee valgus angle and fatigue are major risk factors for ACL injury, basketball players with DKV patterns following fatigue application need to be conscious of the differential valgus angle between their dominant and non-dominant foot. Therefore, the present study was conducted to examine the valgus angles of both the dominant and non-dominant feet in basketball players exhibiting DKV patterns after the application of fatigue.

Materials and Methods

The study's statistical population included male basketball players in the semi-professional league from Kermanshah Province, Iran who were between the ages of 16 and 26 years and had a DKV angle of more than 8 degrees. With the aid of G*Power software, version 3.1 and findings from a prior study [18], the sample size for the current investigation was established. Based on this, the software calculated a sample size of 27 people with a test power of 80% and a confidence level of 0.95. Considering the potential dropout of participants, three additional individuals were included in each group beyond the sample size calculated by the software. Before the commencement of the study, participants completed medical and sports information questionnaires, and a consent form was obtained. Before the study, we conducted a briefing session to provide participants with sufficient information about the research and to assure its safety. The inclusion criteria included participants who were men and within the age range of 16 to 26 years and had DKV defects. They had engaged in basketball training for a minimum of two years and three times a week. The exclusion criteria included those who had experienced injury or surgery, significant cardiovascular, respiratory, or neurological disorders in the past six months, or had structural valgus or varus.

Anthropometric measurements, including height, weight, shoulder width, hip width, leg length, medial-lateral knee joint distance, external and internal malleolus distance, and Q angle, were obtained using a digital stadiometer (Inbody BSM 170, Japan), a smart scale (Mi-Smart-Scale2, China), a caliper (Mitutoyo, Japan), and a goniometer [19]. We placed reflex markers between the first and second metatarsal joints (figure 1), on the tibial tuberosity (Figure 2), and the anterior superior iliac spine (Figure 3) on both sides [19]. The tuck jump assessment (TJA) was utilized for initial screening to identify DKV patterns [20]. To do the TJA, participants had to stand with their feet shoulder-width apart and jump vertically, trying to lift their knees as high as possible. At the apex of the jump, the thighs should be parallel to the floor. Participants were told to start the following tuck leap after landing. Under the examiner's supervision, this test was run for 10 s [19]. After meeting the criteria to enter the assessment, participants were then prepared for further evaluations. Their angle of incidence should be more than 8 degrees [21]. After the selection of eligible players, each one was prepared at the sports facility's dedicated basketball court at 5:00 PM with prior coordination. Angles were recorded using a camera and a filming tripod. The camera tripod was adjusted relative to the

PHYSICAL TREATMENTS

Figure 1. Between the 1st and 2nd metatarsal joints

Figure 2. Patellar center

PHYSICAL TREATMENTS

subject's height and in a frontal view [22]. After selecting eligible participants, each was instructed to stand in the designated area and perform three countermovement jumps [23]. The average of the three jumps was recorded using a camera (Nikon d300). Subsequently, the knee valgus angle was measured using KINOVEA software, version 0.9.5. In this study, the basketball fatigue protocol lasted for 40 minutes [24]. During the game, only athletes can drink water to achieve the game's control over food and fluid intake. The participants received an assessment after the game using the Borg rating of perceived exertion (RPE) scale to measure their mental fatigue [24]. All rest periods during the game adhered to those in regular gameplay. After the game, immediately to reduce the fatigue effect, the participant performed three counter-movement jumps again to measure the knee angles. A digital camera recorded the angles and analyzed them using KINOVEA software.

PHYSICAL TREATMENTS

Figure 3. Anterior superior iliac spine

An angle was drawn using three points for the knee joint (anterior superior iliac spine, middle of the patella, and second metatarsal head) to examine the moment of initial contact (Figure 4) and the deepest knee flexion (Figure 5) in the frontal plane during landing. The first frame from the start of the movement was chosen. The final landing frame was then chosen, just like in the previous step, and an angle was once more drawn based on the Figure. To obtain the initial contact and deepest knee flexion angles in the frontal plane, the angle of the knee joint at the time of takeoff (first frame of the jump phase) was finally subtracted from the angle of the knee joint at the time of landing (last frame of the landing phase at initial contact and maximum flexion) [25].

Statistical methods

The study employed descriptive and inferential statistics to examine the unprocessed data obtained. Descriptive statistics, such as Mean±SD, were used to describe the person's dependent variables and demographic char-

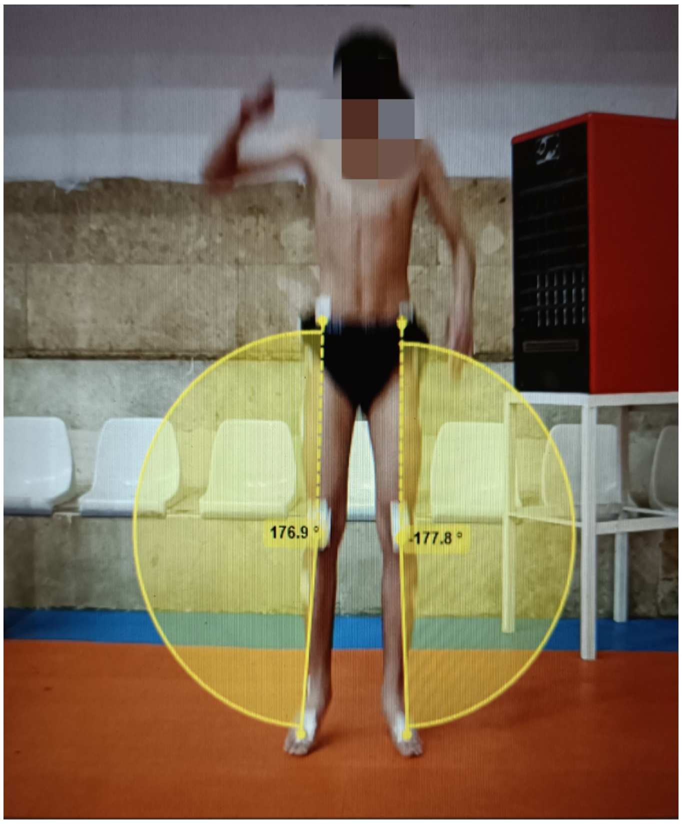

Figure 4. The knee angle (initial contact) in the frontal plane at the moment of landing

PHYSICAL TREATMENTS

Figure 5. The knee angle (maximum flexion) in the frontal plane at the moment of landing

PHYSICAL TREATMENTS

Table 1. General characteristics of participants

Variables	Mean±SD
Age (y)	20.77±3.06
Weight (Kg)	79.68±18.35
Height (cm)	188±9
Body mass index (BMI) (kg/m²)	22.24±3.23
Shoulder width (cm)	33.81±3.94
Pelvic width (cm)	30.01±3.47
Distance ASIS (cm)	26.61±3.01
Knee condyle width (cm)	9.11±1.01
Ankle width (cm)	7.12±0.65
Lower limb length (cm)	94.30±5.40
Q angle (degrees)	9.38±0.81
Borg RPE	7.88±0.8

Abbreviations: RPE: Rating of perceived exertion; ASIS: Anterior superior iliac spines.

PHYSICAL TREATMENTS

acteristics. We used the Shapiro-WILK test to determine the normality of data distribution. For every movement task, we utilized paired t-ests to see if the data had a normal distribution. Ultimately, the study's raw data were compiled into an Excel spreadsheet and subjected to analysis using IBM Corp.'s SPSS software, version 23 (Armonk, NY, USA). Notably, this study's significance level was established at 95% with an alpha threshold of 0.05 or below.

Results

Table 1 lists the Mean±SD of the participant's demographic characteristics, including age, weight, height, body mass index (BMI), shoulder width, hip width, anterior superior iliac spines (ASIS) distance, knee condyle width, ankle width, lower limb length, Q angle and Borg RPE.

Table 2 presents descriptive statistics, including the Mean±SD, for the research variables.

Discussion

This study was conducted to compare dominant and non-dominant knee valgus angles in basketball players with DKV deficiency after fatigue. According to the study, basketball players had a larger dominant knee valgus angle than their non-dominant knee valgus angle, but the functional loss brought on by tiredness did not increase the knee valgus angle. A related study conducted by Ford et al. involved measuring the amount of knee valgus movement and the varus-valgus angle during vertical jumps among 81 basketball players (47 females and 34 males). The method employed was to have individuals jump from a box and immediately jump upwards. After analyzing the landing phase, it was determined that the valgus angle differs significantly between the dominant and non-dominant leg [26]. Similarly, Brophy et al found that fatigue did not affect the mechanisms of the ACL [27]. The fatigue did not affect the knee angle in the current study due to the results of simulated exercises with an actual game. Additionally, other factors, such as players' readiness level and sports discipline, also play a significant role in this matter. Ilaghi-Hosseini et al. found a substantial variation in the knee angle changes between the non-dominant and dominant legs, which is consistent with the results of this investigation [28]. Additionally, Ludwig et al reported a significant difference in the kinematics of the dominant and non-dominant legs during single-leg landing in football players after researching 66 professional players and 48 amateur players [29]. They reported greater stability during single-leg landing in the non-dominant leg compared to the dominant leg. In another study consistent with the results of the present study, Izawa et al. reported that gender and dominant/non-dominant legs significantly affect shock absorption capacity during landing. Moreover, vertical ground reac-

Table 2. Paired t-test for the intragroup comparison of the mean research variables

Variables	Time	Mean±SD	Mean Difference	t	df	Sig	η_p^2
Pre- and post-test valgus initial contact of the dominant leg (degrees)	Pre-test	2.03±2.64	0.05	0.127	26	0.900	0.001
	Post-test	2.38±2.59					
Pre and post-test valgus initial contact of the non-dominant leg (degrees)	Pre-test	2.93±2.24	0.70	1.547	26	0.134	0.084
	Post-test	2.86±1.54					
Pre and post-test valgus maximum flexion of the dominant leg (degrees)	Pre-test	3.66±9.46	-0.75	-1.109	26	0.237	0.053
	Post-test	3.74±10.21					
Pre and post-test valgus maximum flexion of the non-dominant leg (degrees)	Pre-test	5.01±5.70	-0.95	-1.351	26	0.188	0.066
	Post-test	6.04±6.65					
Pre-test valgus initial contact of both dominant and non-dominant legs (degrees)	Pre-test dominant	2.03±2.64	0.40	0.709	26	0.485	0.109
	Pre-test non-dominant	2.93±2.24					
Post-test valgus initial contact of both dominant and non-dominant legs (degrees)	Post-test dominant	2.38±2.59	1.05	1.918	26	0.066	0.124
	Post-test non-dominant	2.86±1.54					
Pre-test valgus maximum flexion of both dominant and non-dominant legs (degrees)	Pre-test dominant	3.66±9.46	3.75	2.704	26	0.012*	0.219
	Pre-test non-dominant	5.01±5.70					
Post-test valgus maximum flexion of both dominant and non-dominant legs (degrees)	Post-test dominant	3.74±10.21	3.55	2.516	26	0.018*	0.196
	Post-test non-dominant	6.04±6.65					

*Significance level (P≤0.05).

PHYSICAL TREATMENTS

tion force and internal ground reaction force, which are risky factors for knee injury during landing, are higher in women than men and in the non-dominant leg compared to the dominant leg [30]. Consistent with the results of the current investigation, Bila et al. concluded that cutting and landing motions on the non-dominant leg differ from those on the dominant leg [31] . Research indicated a higher likelihood of knee injury and increased valgus during the end of the game compared to before the game starts; for example, in a study that contradicts the present research, chappell et al concluded that both groups of men and women experienced increased knee valgus movements during landing after fatigue [6]. The reason for this difference in results between the present study and Chapelle's study can be players' readiness level because in the present study, semi-professional players participating in the country's first division league were involved and with up-to-date training, they may have achieved better compatibility with basketball skills. The results of the present study contradict the research of Murphy and Dickin (2015) because they stated in their separate study that fatigue can increase the likelihood of ACL injury during landing by altering kinematic variables [32, 33]. However, in the present study, a 40-minute basketball game did not result in a change in knee valgus angle, which could be caused by the exhaustion protocol that was employed.

Conclusion

The study's results demonstrated that basketball players' dominant and non-dominant legs have different knee valgus angles, with the dominant limb having a larger knee valgus angle than the non-dominant leg. Also, the results showed that fatigue does not raise the players' knee valgus angle. The semi-professional players taking part in the country's first division league, who were involved in the present study, may have improved their compatibility with basketball skills through up-to-date training due to their readiness level. By obtaining the results, it is possible to better understand the kinetic indicators in dangerous situations, which can help athletes learn the proper techniques to use in such dangerous situations.

Limitations

Lack of control over daily physical activity and routine life activities. Lack of control over the psychological and motivational state of the participants. The intensity of occupational work and the level of daily activity. Lack of control over individual differences and genetic factors of the participants.

Ethical Considerations

Compliance with ethical guidelines

This research received approval from the Ethics Committee at the University of Guilan (Code: IR.GUILAN.REC.1402.083).

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Authors' contributions

All authors equally contribute to preparing all parts of the research.

Conflict of interest

The authors declared no conflict of interest.

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